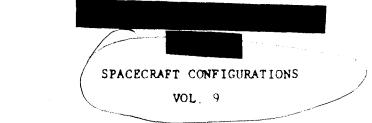
WDL-TR2366 2 January 1965



COMET AND CLOSE-APPROACH ASTEROID MISSION STUDY FINAL REPORT

The work was sendomind for the Jet Propulsion Laboratory. All forms. Institute of Technology, apposited by the particle Advantage and Space Advancements under a correct AAS7-100.

Prepared for

Jet Propulsion Laboratory
Pasadena, California

from the launch vehicle. Active damping is necessary at the solarpanel hinge points to reduce the cantilever vibration modes of the
panels during operation of the spacecraft propulsion system. The trapezoidal panels shown in the drawing represent the maximum area required,
except for Brooks (2). A mission to Brooks (2) requires two unsymmetrical
panels in order to provide the forward field of view required by the
approach geometry. For missions to Pons-Winnecke and Kopff, the smaller
panel areas and the more favorable approach geometry lessen the view
interference by the solar panels.

2.3 ANTENNAS

A parabolic antenna, elliptical in plan view, is fixed on the forward surface of the octagonal compartment. The RF axis is permanently oriented toward the earth at the time of comet intercept. The orientation is somewhat different for each comet mission. For a maximum rigidity—to-weight ratio, aluminum honeycomb construction, such as used on Mariner-C, appears the most desirable. A rather thorough test program is necessary to determine the effect of thermal distortion (which could be quite large for this type of construction) on the RF radiation pattern. Philoo-WDL is now studying a similar problem for NASA-Ames [Philoo, 1964].

A 3.5-inch diameter tubular wave guide approximately 62 inches long serves as the low-gain antenna. It is mounted on top of the equipment compartment with its longitudinal axis parallel to the spacecraft roll axis. The antenna provides uniform coverage over the forward hemisphere of the spacecraft. Its length is such that it will operate in the event of solar-panel deployment failure.



2.4 SCIENTIFIC INSTRUMENTS

Scientific instrument locations are in accordance with the following schedule and are illustrated in Figure 2-1:

- a. Magnetometer and Integrating Ionization Chamber. Because of their respective requirements for small spacecraft magnetic field and near-omnidirectional view of space, these instruments are loacted on a 15- to 20-foot boom extended normal to the spacecraft roll axis. One boom suffices for both instruments. The boom is a pneumatically operated telescoping type (e.g., Ranger Program, Blocks I and II), and is designed to provide adequate stiffness and damping during spacecraft velocity corrections. Unfurlable booms (e.g., DeHavilland Aircraft, Ltd.) appear to offer no advantages until longer lengths are required. A reliable method of furling the boom during velocity corrections would then be necessary. The reliability of such an operation after a long period in space has not yet been demonstrated.
- b. <u>Dust Detector</u>. Two detectors are located on top of the octagonal compartment. The active surface of one detector is oriented normal to the spacecraft velocity vector; the other detector's surface is oriented along the velocity vector at right angles to the first detector such as to face the nucleus at encounter.
- c. <u>Plasma Probe</u>. This instrument is located on top of the main compartment with its axis pointed along the roll axis of the spacecraft (probe-sun line).
- d. <u>Ion Mass Spectrometer and Ion-Electron Trap</u>. This instrument is located on top of the main compartment with its axis oriented along the velocity vector.



e. <u>Ultraviolet Spectrophotometer</u>, Infrared Photomultiplier Radiometer or Ultraviolet Photometers, Slow-Scan Television. These three comet viewing experiments, along with a comet tracking device, are housed together below the octagonal compartment. During the encounter mode of operation, this assembly tracks the nucleus of the comet by rotating with respect to the spacecraft about two axes. It can traverse 360° (clock angle) about an axis parallel to the spacecraft roll axis, and, when the support yoke is erected, elevate through a 210° angle (cone angle). The exact location of this package (with respect to the pitch and yaw axes) depends on the comet mission chosen. In all cases the comet is assumed to pass on the anti-solar side of the spacecraft. Some encounter geometries require a view forward to within as little as 30° of the roll axis. To meet this requirement, the assembly must be located so that its view is not obscured by the solar panels or by the main compartment. Fortunately, at the time that forward viewing is required, the clock angle is constant, and therefore the assembly can be located so as to look between the solar panels.



SECTION 3 ISOTOPIC CONFIGURATION

3.1 BASIC SPACECRAFT

The Isotopic Configuration is formed by removing the solar panels of the Photovoltaic Configuration and adding an isotopically heated thermoelectric generator. As illustrated in Figure 3-1, the power supply is supported above the main compartment by a truss framework. This method of support provides the power supply radiator fins with the good view of space for efficient operation. Because of the high temperatures at the truss interface with the power supply, titanium is used for the main truss members. Its high strength at elevated temperatures and relatively low thermal conduction make it an ideal material for such use. Stainless steel has been rejected because of its higher magnetic permeability. The lower end of the longitudinal truss members attaches to the octagonal compartment by means of hydraulic dampers. It is anticipated that the inclusion of such damping is necessary to reduce the dynamic stresses in the trust during launch.

The removal of the solar panels alleviates the encounter viewing problems that arise when the comet is well forward of the spacecraft. A comet can now be tracked that has a trajectory parallel to the spacecraft roll axis.

The isotopic power supply presents a clear weight advantage over solar power for a mission to Brooks (2). From the standpoint of power density the advantage is far greater. The amount of payload envelope volume consumed in stowing 90 ft² of solar panels (even if some degree of panel articulation is allowed) presents a severe handicap to the optimization of the rest of the spacecraft. Furthermore.



SPACECRAFT CONFIGURATIONS

VOL. 9



SUMMARY

Two configurations have been developed based upon the use of the Atlas-Centaur launch vehicle. Except for the power supplies, both configurations are identical and bear a close resemblance to the Mariner-C spacecraft. The resemblance of the configurations to the Mariner-C spacecraft means that maximum advantage can be taken of that technology and experience. An important difference from Mariner is that, by using an Atlas-Centaur, stringent weight and payload volume restrictions are not present. The projected weight of either configuration is 700-800 pounds,

Two configurations have been discussed for an Atlas-Agena mission to Pons-Winnecke. The Spacecraft are modified versions of the Mariner-C design and represent minimal and extended modification cases.

The Atlas-Centaur Photovoltaic configuration is recommended for most missions (e.g. Kopff 1970) except Pons-Winnecke and Brooks (2). The use of the proven Mariner spacecraft design, even though modifications are necessary, is recommended for Pons-Winnecke missions in late 1969 and early 1970. The minimal modification configuration is recommended unless the inclusion of a high-resolution, highly sensitive TV system becomes a high-priority scientific objective. In that case, an extended redesign of the Mariner-C is recommended.

The Atlas-Centaur RTG configuration appears attractive for the Brooks (2) 1973 mission because of the large solar panel area required. On the other hand, because of the larger volume Surveyor payload envelope and the payload weight available with the Atlas-Centaur, such panels can be accommodated in the interest of using proven technology.



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SECTION 1 OBJECTIVES AND REQUIREMENTS

1.1 DESIGN REQUIREMENTS

It is the intent of this study to indicate a desirable physical integration of operational sybsystems rather than to present a detailed spacecraft design. In this sense the configuration drawings may be considered to represent "block diagrams" of a spacecraft to satisfy the mission requirements. The following objectives and requirements have been guidelines for developing spacecraft configurations:

- 1. Physically integrate the subsystems by means of a rigid, lightweight structure. Objectives of this integration, or packaging, are the following:
 - a. Facility with which subsystem packages may be assembled and tested prior to final assembly into the spacecraft.
 - b. Facility of subsystem removal for repair, retest, or replacement.
 - c. Ease with which subsystem units may be handled and shipped prior to final assembly.
 - d. Use of modular construction for the basic equipment compartment to minimize fabrication cost and to maximize subsystem location flexibility.
- 2. Accommodate a high-gain, 28" x 48" parabolic-section antenna having a fan-beam pattern in the ecliptic plane. For this design it is assumed that the RF axis is permanently oriented with respect to the spacecraft.
- 3. Accommodate a low-gain antenna providing essentially uniform coverage in the forward hemisphere of the spacecraft. Forward is defined as the direction toward the sun.



- Accommodate a post-injection propulsion system capable of producing up to 150 meters-per-second velocity increment.
- 5. Utilize one of two possible on-board power supplies:
 - a. A photovoltaic array having a panel area of 58 to 90 square feet.
 - b. An isotopic power supply requiring a nearly omni-directional view of space.
- 6. Provide a large field of view for a comet-tracking assembly housing certain encounter mode scientific experiments. The design assumes that the comet passes on the anti-solar side of the spacecraft.
- 7. Conform to the Centaur launch vehicle interface with the R&D or Surveyor payload envelope.

Consideration of these requirements and objectives has led to the development of two basic configurations whose difference is dictated by the choice of on-board power systems. The spacecraft are referred to as the Photovoltaic Configuration and the Isotopic Configuration; a description of each follows below.



SECTION 2 PHOTOVOLTAIC CONFIGURATION

2.1 MAIN EQUIPMENT COMPARTMENT

The main equipment compartment of this spacecraft, shown in Figure 2-1, is an octagonal structure providing eight bays in which to package equipment. The size and construction of the compartment is the same as that of the Mariner-C spacecraft, except for the use of heavier gage material. The dimensions of the compartment can be extended somewhat should the need for more equipment volume become necessary. As in the case of Mariner-C, seven of the eight bays supply packaging volume for the majority of the electronic equipment. The eighth bay contains the propulsion subsystem with its thrust axis aligned in the ecliptic plane approximately normal to the roll axis of the spacecraft. Fuel and coldgas supply tanks are located in the eighth bay and center compartment. Sun sensors are located on the top and bottom of the compartment. The compartment is supported during launch on a 7-inch-high interface adapter ring in order to provide space under the compartment for the comet tracking assembly and Canopus tracker. The spacecraft separation interface is at the top of this ring structure.

2.2 SOLAR PANELS

Attached to the basic compartment are four erectable solar panels on which to mount the solar cells. Four solar pressure vanes are attached to the ends of the panel structures. The R&D envelope allows 75 square feet of area, while the Surveyor envelope allows the 90 square feet required on a mission to Brooks (2) at 200 watts power. The panels are supported by a hydraulically damped structure during launch and deployed into a plane normal to the spacecraft roll axis after its separation



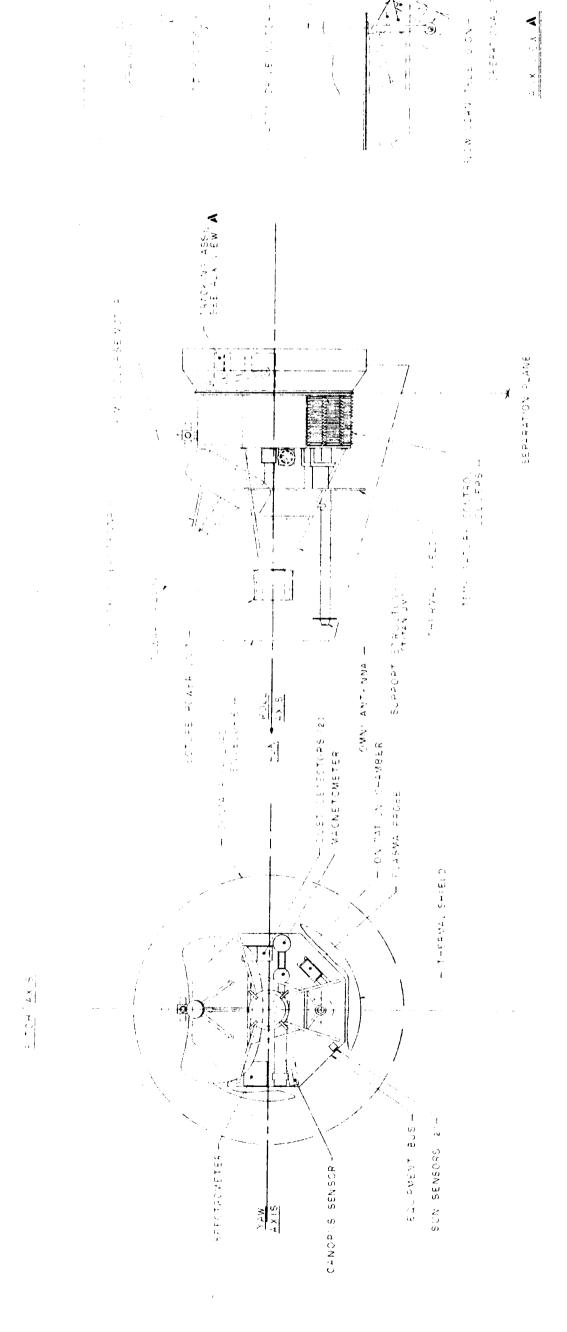


Fig. 3-1 Comet Probe Isotopic Power

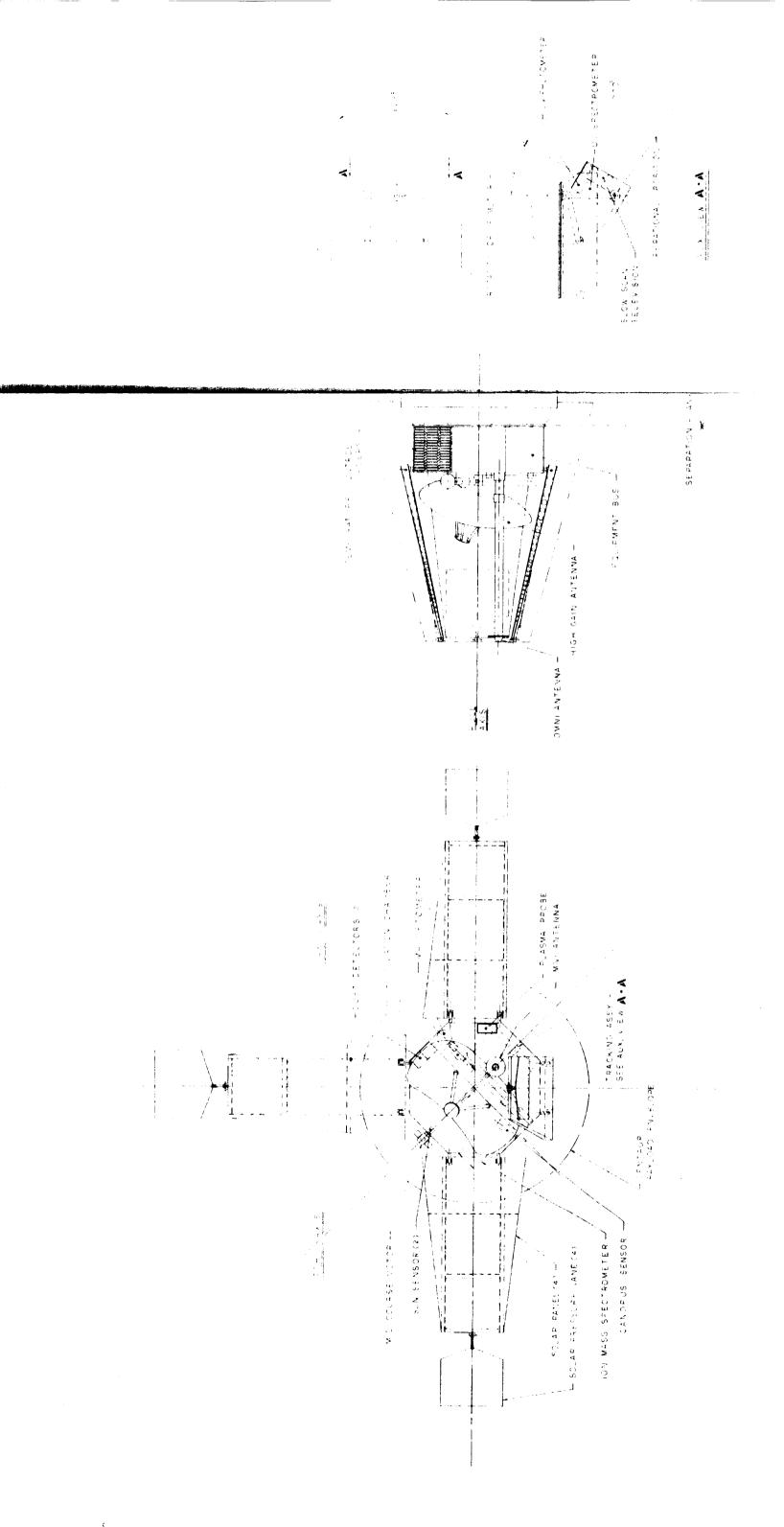


Fig. 2-1 Comet Probe Photovoltaic Power

the isotopic configuration has a growth potential should more power be required; the photovoltaic configuration must be considered to be near the end of practicality.



SECTION 4

ADAPTABLE SPACECRAFT

4.1 COMET MISSIONS

The adaptability to several comet missions is built into the photovoltaic and isotopic spacecraft designs described in the previous section. The adaptation of either design to a particular comet necessitates changes in the following areas:

- a. On-Board Power The isotopic package is the same for all missions. The photovoltaic configuration requires different panel areas for each comet.
- High-Gain Antenna The antenna orientation is somewhat different for each mission.
- c. Comet Tracking Assembly The location of the comet tracking assembly is under either Bay 3 or Bay 7 of the main compartment, depending on the encounter geometry of the particular comet.

 The variable location is necessary because the cometary encounter trajectories are not normal to the spacecraft roll axis and hence pass to one side or the other of the spacecraft. Solar-side passage of the comet is assumed for missions requiring observations of the nucleus.
- d. Post-Injection Propulsion System It may be desirable to tailor the fuel tankage for each mission if a wide variation in velocity increments develops among comets.

With these adaptations, either configuration is amenable to any of the comet missions analyzed. The design of a configuration that can meet



all mission requirements without some changar does not appear feasible.

4.2 CLOSE-APPROACH ASTEROID MISSIONS

The comet probe configurations are adaptable to solar-side fly-by asteroid missions. The changes outlined in Section 4.1 are necessary to adapt the spacecraft to a particular asteroid mission. The comet tracking platform can be used to track the asteroid and contains the asteroid viewing experiments.

If the mission objectives go beyond those of a simple fly-by, such as firing projectiles at the asteroid, more changes must be expected in the spacecraft configurations. The exact degree of applicability of the comet probe to an asteroid mission must await a more complete definition of its mission requirements.



SECTION 5

A MARINER-C COMET PROBE

5.1 ADAPTATION OF MARINER-C SPACECRAFT TO A COMET MISSION

An Atlas/Agena has sufficent payload capability for a mission to Pons-Winnecke. Additional cometary opportunities may exist, but their investigation and discussion are not within the scope of this document.

Based on a 30-day launch window, payloads of 630 and 578 pounds are available for a Pons-Winnecke fly-by using Type I and Type II trajectories respectively. This capability suggests the use of a modified Mariner-C. The degree of change from the present Mariner-C configuration depends upon whether the spacecraft is optimized for the mission at the expense of utilizing present Mariner technology. It is possible, for instance, to change only the orientation of the high-gain antenna and fly an otherwise unaltered Mariner. The other end of the modification scale cannot be defined within the scope of this study. Two points on the modification scale have been chosen for discussion. They represent near-minimal and maximal cases and correspond to the Type II- and Type I- trajectory payloads respectively.

5.2 TYPE-II TRAJECTORY SPACECRAFT

The first step in the modification of the spacecraft design is the removal of unnecessary or unusable equipment. The Planet Scan Assembly has only one degree of freedom and hence is unsuitable for cometary tracking at encounter. The unit is therefore removed along with the TV subsystem which lacks sufficient sensitivity to view the nucleus at the nominal fly-by miss distance of 5,000 km. The tape recorder is



retained in order to permit a higher science data sampling rate at encounter. The solar panel area of 70 sq. ft. can be reduced by approximately 15 sq. ft. to 55 sq. ft. because of the higher solar intensity at encounter. This reduction includes designing for a giant solar flare.

In order to achieve a 5000-km nomical miss distance, a PIPS capability of 120 m/sec must be provided. Hence, increased fuel capacity must be added to the configuration. It is assumed that the present midcourse motor design is adequate for the resulting increased burn time.

In addition to these required modifications, additions to the scientific payload are desirable. With the high data capacity of the tape recorder now available at encounter, an Ion-Mass Spectrometer can be accommodated. In addition, a gimbaled Comet Tracking Assembly can be designed to replace the removed Planet Scan Assembly. Integrated with the tracking unit are UV photometers. At encounter, the spacecraft referenced comet trajectory is nearly perpendicular to the spacecraft roll-axis. Hence, it does not appear necessary to extend the Comet Tracking Assembly from the main compartment of the spacecraft as in the configurations (Figures 2-1 and 3-1) designed to accommodate the comet tracking requirements of several comet encounters.

An estimated weight summary for the Type-II trajectory Mariner-C modifications is given in Table 5-1. No weight penalty is incurred in reorienting the high-gain antenna. Electronic assembly changes (such as those to the DAS to permit a high data rate at encounter) are assumed to require no weight increase within the accuracy of the estimate.



Table 5-1 Weight Summary Type-II Trajectory Modifications to Mariner-C Spacecraft (1969)

Basic Mariner-C Spacecraft Weight		565 1ъ
Remove		
Planet Scan Assembly	15	
TV Electronics	8	
Scan Electronics	4	
15 sq. ft. from Solar Panels	15	
Total Removed Weight		42
Reduced Spacecraft Weight		523
Add		
Increase PIPS Capability to 120 m/sec	16	
Ion-Mass Spectrometer	8	
Gimbaled Comet Tracker, UV Photometers, and Electronics	25	
Installation Allowance	1	
Total Added Weight		50
Modified Spacecraft Weight		573 lb
Type-II Trajectory Capability		578 lb
Margin		5 lb



5.3 TYPE-I TRAJECTORY SPACECRAFT

This configuration differs from the former by its accommodation of a higher sensitivity TV subsystem (Advanced Mariner type). Integrating the TV electronics modifies the input to one of the communications assemblies. The TV camera is located along with UV photometers on a large comet tracking assembly mounted below the center of the octagonal compartment. The height of the Agena/spacecraft adapter is increased to provide the volume needed to stow the assembly. Resizing the solar panels down to 55 sq. ft. permits the octagonal structure to be raised. The midcourse motor must be repositioned to accommodate the change in center of gravity.

Table 5-2 outlines the weight summary for this configuration.



Table 5-2 Weight Summary Type I - Trajectory Modifications to Mariner-C Spacecraft (1970)

Basic Mariner-C Spacecraft Weight	565 lb	
Total Removed Weight (Table 5-1)	42	
Reduced Spacecraft Weight		523 lb
Add:		
Increase PIPS Capability to 80 M/sec for 640 lb spacecraft	2 1b	
Ion-Mass Spectrometer	8	
Comet Tracking Platform Assembly Electronics	20	
Comet Tracker	10	
Advanced-Mariner TV System (or UV Spectrometer and Ion-Electron Trap*)	35 (22) (8)	
UV Photometers	6	
Increase Height of Spacecraft/Agena Adapter by 6 in.	16	
Installation Allowance	3	
Total Added Weight		100 lb (or 95)
Modified Spacecraft Weight		623 lb (or 618)
Type-I Trajectory Capability	630 lb	
Margin	7 lb (or 12)	

^{*}Ion-Electron Trap Not On Tracking Assembly



SECTION 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 SPACECRAFT CONCEPTUAL DESIGNS

Two configurations have been developed based upon the use of the Atlas-Centaur launch vehicle. Except for the power supplies, both configurations are identical and bear a close resemblance to the Mariner-C spacecraft. The resemblance of the configurations to the Mariner-C spacecraft means that maximum advantage can be taken of that technology and experience. An important difference from Mariner is that, by using an Atlas-Centaur, stringent weight and payload volume restrictions are not present. The use of heavier gage structural materials is permitted and recommended. Their use will alleviate the handling, testing, and analysis problems associated with very light construction. Present state-of-the-art materials and fabriaction methods are envisioned for the structure. The projected weight of either configuration is 700-800 pounds. This figure is below the payload capability of the Atlas-Centaur. A weight breakdown by principal subsystem is given in Table 6-1.

6.2 MARINER-C COMET PROBE

Two configurations have been discussed for an Atlas-Agena mission to Pons-Winnecke. The spacecraft are modified versions of the Mariner-C design and represent minimal and extended modification cases. The weight breakdowns for these two cases and for the launched Mariner-C are given in Table 6-2.

6.3 CHOICE OF SPACECRAFT CONFIGURATION

The Atlas-Centaur Photovoltaic configuration is recommended for most missions (e.g. Kopff 1970) except Pons-Winnecke and Brooks (2). The use



Table 6-1. Weight Breakdown for Atlas-Centaur Comet Probes

SUBSYSTEM		PHOTOVOLTAIC CONFIGURATION	ISOTOPIC CONFIGURATION
Structure	90	110	110
Interface	20		
Science			
Tracking Platform	26	152	152
TV-Tracker	16		
Encounter Science	50		
Cruise Science	40		
Boom	10		
DAS	10		
Attitude Control		80	80
Midcourse Propulsion (150 m/s)		100	100
Telecommunication	100	110	110
Antennas	10		
Thermal Control		30	30
Power (200 w)		119-162	110
Panels or Isotopic Unit		69-112	70
Isotope Support Structure		10	
Power Conditioning		10	••
Batteries		40	30
System Total - 200 w		701-744	692
- 300 w		737-800	742

Table 6-2. Mariner-C Comet Probe
Weight Breakdowns

MARINER-C SUBSYSTEM	TRAJECTORY-II MODIFICATION (late 1969)	MARI- NER-C (1964)	TRAJECTORY-I MODIFICATION (Early 1970)
SCIENCE			
Comet Tracker & Experiments Independently Mounted Experiments Electronics & DAS	25 16 36	15 8 48	71 16 36
GUIDANCE AND CONTROL			
Attitude Control; CC & S Gas System Sensors	39 29 7	39 29 7	39 29 7
PROPULSION			
Midcourse Motor	66	50	52
TELECOMMUNICATION			
Data Encoder & Command RF & Tape Recorder Antennas	42 64 10	42 64 10	42 64 10
POWER			
Panels Regulator Conditioning Battery	63 16 32 33	78 16 32 33	63 16 32 33
THERMAL CONTROL			
Thermal Control Assemblies	13	13	13
STRUCTURE			
Pyro & Actuators Structure Cabling	6 59 17	6 58 17 565 1	7 76 17 623 1b
	573 1b	ז כסכ	023 10

of the proven Mariner spacecraft design, even though modifications are necessary, is recommended for Pons-Winnecke missions in late 1969 and early 1970. The minimal modification configuration is recommended unless the inclusion of a high-resolution, highly sensitive TV system becomes a high-priority scientific objective. In that case, an extended redesign of the Mariner-C is recommended.

The RTG Configuration appears attractive for the Brooks (2) 1973 mission because of the large solar panel area required. On the other hand, because of the larger volume Surveyor payload envelope and the payload weight available with the Atlas-Centaur, such panels can be accommodated in the interest of using proven technology.



SECTION 7 REFERENCES

Philco, <u>Study of Parabolic Antenna Distortion</u>, under NASA-Ames Contract NAS-2-2564; 1964-1965.

